DOCUMENT RESUME

ED 306 085 SE 050 463

AUTHOR Radford, David L.
TITLE Promoting Learning through the Use of Analogies in High School Biology Textbooks.
PUB DATE 89
NOTE 28p.; Paper presented at the Annual Meeting of the National Association for Research in Science Teaching (62nd, San Francisco, CA, March 30-April 1, 1989).
PUB TYPE Speeches/Conference Papers (150) -- Reports - Research/Technical (143)

EDRS PRICE MF01/PC02 Plus Postage.
DESCRIPTORS *Biology; Cognitive Structures; *Concept Formation; Evolution; High Schools; Instructional Materials; Models; Science Instruction; *Secondary School Science; Textbook Evaluation; *Textbook Preparation; Textbook Research; *Verbal Development
IDENTIFIERS *Analogies

ABSTRACT

A model for developing instructional analogies was used to produce experimental treatments that included text from a high school biology textbook to which was added extended verbal analogies written by the researcher linking each of two biology concepts to analogous familiar concepts. The control treatment was text from the biology textbook retyped in the same format as that of the analogy text. Students randomly assigned to experimental or control treatment within each of nine classrooms read the texts on the topics of evolution and cellular respiration and took immediate and delayed recall content achievement tests. Results included significant differences in biology achievement in favor of the analogy treatment group on the immediate recall test on the evolution topic and on the delayed recall test which covered both topics. An achievement difference on the immediate recall test of the respiration topic, while in favor of the analogy treatment group, was nonsignificant. Teachers and textbook authors are encouraged to use the parts of the model supported by the results of this study for developing effective instructional analogies. (Author)

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Promoting Learning Through the Use of Analogies In High School Biology Textbooks

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Paper presented at the annual meeting of the
National Association for Research in Science Teaching
San Francisco, California
March 1989

SE 050 463

Abstract

A model for developing instructional analogies was used to produce experimental treatments that included text from a high school biology textbook to which was added extended verbal analogies written by the researcher linking each of two biology concepts to analogous familiar concepts. The control treatment was text from the biology textbook retyped in the same format as that of the analogy text. Students randomly assigned to experimental or control treatment within each of nine classrooms read the texts on the topics of evolution and cellular respiration and took immediate and delayed recall content achievement tests.

Results included significant differences in biology achievement in favor of the analogy treatment group on the immediate recall test on the evolution topic and on the delayed recall test which covered both topics. An achievement difference on the immediate recall test of the respiration topic, while in favor of the analogy treatment group, was nonsignificant.

Teachers and textbook authors are encouraged to use the parts of the model supported by the results of this study for developing effective instructional analogies.

Promoting Learning Through the Use of Analogies In High School Biology Textbooks

Introduction

"The mitochondrion is the powerhouse of the cell."

"Photosynthesis is a bridge between the inorganic and organic worlds."

"A DNA molecule is like a twisted ladder with pairs of nitrogen-containing molecules uniting to form each rung."

These and similar simple analogies are used in biology textbooks in an attempt to increase students' understanding of biology concepts. Analogies have been shown to aid learning in several research studies (Royer & Cabel, 1976; Harris, et al., 1980; Burns, 1984). An analogy's success in promoting learning is influenced by several factors including the appropriateness of the analogy vehicle, the author's explanation of the link between the analogy vehicle and the target learning material, and the placement of the analogy in the text. Each of these considerations will be discussed in the following section.

Characteristics of Effective Analogies

Analogies are used to provide a bridge between the familiar and the unknown, between the simple and the complex. The target of the analogy is the complex or unknown domain. In science instruction, the target will frequently be an abstract concept, such as the structure of an atom or the process of photosynthesis. The analogy vehicle is the familiar domain. For example, the process of baking a cake might be used as a vehicle to teach the target concept of photosynthesis. The vehicle functions to provide a framework for thinking and learning about the target. A primary characteristic of an effective vehicle, then,

is that it must be familiar to the learner. The research of Renner, Grant, and Sutherland (1978), which found that the majority of secondary students were still at the concrete operational level of development, suggests that the most effective familiar vehicle will be concrete. Keane (1987) emphasized the importance of selecting a familiar concrete vehicle (base) domain: "An important general guideline is that, when constructing an analogy, base domains should be drawn from the more general domain of one's everyday knowledge of concrete, physical objects and the interactions between them" (p. 67). Most science textbook authors seem to realize the advantage of concrete vehicles. In a survey of 26 science textbooks, Curtis and Reigeluth (1984) found that 82% of the analogies used related a concrete vehicle to an abstract target and 12% related a concrete vehicle to a concrete target. Only 6% of the analogies had an abstract vehicle. To summarize, effective analogies will have a familiar, concrete vehicle to convey a structure that the learner may use in acquiring the new target knowledge.

Effective analogies have strong links between the target and vehicle domains. For example, an analogy comparing cellular respiration to combustion of fuel in an engine would discuss a list of similarities between the two processes: both require a fuel, both require oxygen to release energy, both produce carbon dioxide and water as waste products, etc. Several researchers recommend a careful mapping of the similarities of the target and vehicle and the explanation of the similarities to the learner (Curtis & Reigeluth, 1984; Glynn, et al., in press). This mapping provides the grounds for the analogy. Gick and Holyoak (1980) found that problem-solving tasks were facilitated more by analogies with many matching attributes than by analogies with less extensive

grounds of similarity. In summary, effective analogies will have strong grounds for linking the vehicle and the target domains and will explain these grounds to the learner.

The instructional effectiveness of an analogy is influenced by its position within the material to be learned. Analogies may be placed in one of three locations in a text: at the beginning as an advance organizer, integrated within the text, or at the end as a summary. Ausubel (1960) stressed the benefits of advance organizers as aids to learning. Analogies placed at the beginning of the material to be learned can serve the function of advance organizers. The learner can gain a familiar framework to use in integrating the new knowledge. The author can refer back to the analogy as the new material is presented, and the reader can recall the analogy as an aid to learning the new material. Curtis and Reigeluth (1984) suggest that the most effective placement of analogies is either as advance organizers or as embedded activators within the text. Embedding the analogy within the instruction allows clarification of the preceding information and can serve as an introduction to subsequent information about the target. Effective analogies, then, should be placed at the beginning of the new material to be learned or be integrated within the material.

Analogies in Science Textbooks

Although analogies are already used in science textbooks, their use is not prevalent. In their survey of 26 science textbooks, Curtis and Reigeluth (1984) found an average of only 8.3 analogies per text. Some of the textbooks contained only one analogy. They further found that the use of analogies seemed to be declining. A comparison between

two editions of two of the textbooks found fewer analogies in the later editions than in the earlier editions of the same text.

The scarcity of analogies in textbooks may be due to the lack of an adequate model for generating effective analogies. Several researchers have suggested models for developing analogies for instructional use (Mayer, 1983; Curtis & Reigeluth, 1984; Keane, 1987; Glynn et al., in press). The following model is a synthesis of the key points from these models and the characteristics of effective analogies as outlined in this paper.

Model for Developing Effective Analogies

These steps are suggested as a procedure for developing effective instructional analogies:

1. Select a vehicle from the likely experience of the intended reader. The purpose of an analogy is to relate the unfamiliar target material to the familiar vehicle. If the vehicle is not within the experience of the reader, then the analogy may add confusion rather than aid in the explanation of the new material. In order to select the proper vehicle, authors must know their audience.

2. Position the analogy as an advance organizer, or integrate it throughout the material to be learned. Advantages of placing the analogy as an advance organizer have already been enumerated above. If the analogy maps well, that is, has many similar elements in the vehicle and target, then it may be more effective to integrate the relevant parts of the vehicle and target throughout the learning material.

3. Remind the reader of the characteristics of the vehicle that will be relevant in the analogy. This step serves two purposes. If the

vehicle selected in step 1 is not within the experience of some of the readers, a brief discussion of the relevant characteristics of the vehicle may help alleviate confusion for those readers. Secondly, reviewing the relevant characteristics of the vehicle serves to focus all readers on the parts of the analogy that will be most useful, those parts that will be related to the similar parts of the target information.

4. Compare the vehicle to the target, point by point. Now that the reader has the relevant characteristics of the vehicle in mind, the framework is in place for acquiring the new knowledge of the target. Each point in the analogy should be compared. The power of the analogy as a learning tool depends to a great extent on the number of points of similarity between the target and the vehicle domains. The author can get the most instructional value from the analogy by making sure that the reader sees each of the key similarities.

5. Caution the reader about how the target material differs from the familiar vehicle. The vehicle and target of an analogy are never a perfect match. The similarities of the two provide the instructional power of the analogy, but the differences may lead to misconceptions in the learner. Several researchers have pointed out the dangers of introducing misconceptions with analogies (Weller, 1970; Curtis & Reigeluth, 1984; Glynn, et al., in press). To avoid introducing misconceptions, the author should explain the limitations of the analogy. Glynn, et al. cites an example from a physics text (Conceptual Physics by Hewitt) of a way to limit misconceptions :

> The water analogy is quite useful for gaining a conceptual understanding of electric circuits, but it does have some limitations. An important one is that a break in a water pipe results in water spilling from the circuit, whereas a break in an electric circuit results in a complete stop in the flow of electricity (p. 526).

By explicit attention to differences between the target and vehicle, an author can prevent many misconceptions from being transmitted to the learner.

The model presented here for generating effective instructional analogies is a starting point for improving the instructional value of science textbooks. This model was used as a guide to construct extended verbal analogies that were tested in this empirical research study. The purpose of this study was to investigate the effects of extended verbal analogies on students' immediate and delayed recall of science content.

Research Procedures

The study was conducted at a comprehensive high school in north Georgia. The students who participated were approximately 200 tenth graders who were enrolled in average and advanced level biology courses. Three biology teachers agreed to allow the researcher to conduct the experiment with three of their biology classes. A stratified random sampling technique was used to select the experimental treatment and control groups. In order to control for possible effects of time of day, different classrooms, etc., random assignment to the experimental and control groups was done in each class. Assignment to each group was alternated to maintain balanced samples. The experimental design required each student to read passages on two biology topics. To control for possible effects of order of reading the passages, students within each group (experimental or control) were randomly assigned to read either topic one first, or topic two first.

The experiment was conducted during regular biology class time. All treatment was provided through written passages; the teacher was

not involved in the instruction. Each teacher handed out numbered treatment booklets to the students according to a list provided by the researcher identifying which student got which booklet. The teacher read directions to the students prepared by the researcher. Students were instructed to read about the selected biology concept in preparation for a quiz on that topic. They were told that when they had completed reading the passage they were to turn in the booklet and pick up and take a quiz that covered the topic they had studied. The reading passages were designed so that most students completed reading them in 20 minutes or less. The teacher was instructed to allow students to spend as much time reading the passage as they desired, up to 30 minutes. After 30 minutes the teacher asked any students who had not taken the quiz to do so at that time. Students completed the 20 question multiple-choice quiz in 10 minutes or less. The treatment and quiz were completed within one 50 minute class period. The same procedure was repeated for a second content passage on a different topic the next day.

Treatments

Two treatments were contrasted. Both treatments included written passages approximately eight pages long on two different biology concepts from the students' biology textbook, Modern Biology (Otto & Towle, 1985). The passages for Treatment 1 also contained extended verbal analogies generated by the researcher. The passages for Treatment 2 (the Control) contained verbatim text from the textbook. Both treatment versions were retyped and printed with a high quality laser printer on standard 8.5 x 11 paper.

The topics for these passages were the concepts of cellular respiration and evolution. Both topics had been studied by the students at the beginning of the school year. These topics were selected because they involve abstract concepts that are usually difficult for students to understand. The topics being studied by the biology students at the time of the experiment (characteristics of each class of vertebrates) were much more concrete. A major benefit of analogies in science instruction is their ability to link abstract target concepts with familiar concrete vehicles. In order to test the instructional value of analogies, abstract target concepts were used.

Treatments for the first topic consisted of written passages on the concept of evolution. The model for developing effective analogies presented previously was used as a guide in creating the experimental text containing analogies. One characteristic of effective analogies is that they provide a familiar vehicle to aid the student in learning the unfamiliar target concepts. The vehicle chosen for the evolution topic was the automobile industry. High school students can be expected to have some familiarity and interest in automobiles.

For each concept related to evolution a matching similar concept related to automobiles was selected. The concept pairs were then integrated throughout the content presentation. For example, the target concept of speciation was related to changes in a model of automobile. The following paragraph from the experimental version of the text illustrates the use of the car model analogy to aid understanding of the target concept of species formation.

A species is like one particular model of car, such as a Ford Thunderbird or Chevrolet Corvette. Models change slightly from year to year as they are continuously adapted to the changing market. After a

time, the changes may accumulate such that the car is no longer like the earlier versions of itself. For example, the Ford Thunderbird began as a two-seater sports car, evolved into a large luxury car, then adapted to the oil crisis and changing buyer preference by becoming smaller and sportier again. These different Thunderbirds are very different cars. Very few of their parts are interchangeable. They are so different from each other that they might be considered different "species" within the Ford "genus."

An attempt was made to keep the two treatment versions as similar as possible except for the addition of extended analogies to the experimental version. Three figures included in the textbook were reproduced in both treatment versions. Some modification of the original text was required in order to integrate the analogy into the original text. The addition of analogies to the text resulted in longer text for the analogy version. To maintain a closer balance in length for the two versions, related material from a previous chapter in the textbook was added to the beginning of the control version. The experimental analogy version concluded with a chart relating the target concepts to their corresponding analogy vehicles. To balance for the additional length added by the chart and to compensate for its instructional effects, a summary from the end of the textbook chapter was added to the control version. The net effect of the balancing was to produce a control version that was 7.5 pages long and an experimental version slightly less than 9 pages long. Readability of the two versions was comparable. Reading level on the Flesch-Kincaid scale (Kincaid, 1980) was grade 9 for the analogy text and grade 8 for the control text.

The second topic was cellular respiration. Finding a suitable analogy from the students' everyday experience for the cellular respiration topic proved more difficult than for the evolution topic. Several possible analogies were explored, but none of them mapped well, that is,

very few similarities could be found between the target concept and the vehicle concept. The vehicle finally chosen for the analogy was based on an old joke about a man who left a factory everyday with a load of wood scraps in a wheelbarrow. The guard at the factory door did not understand why the man would go to the trouble of taking worthless scraps until the man confessed the real benefit in his exploits. He was acquiring wheelbarrows!

Since the analogy was constructed from an artificial situation it had several disadvantages, as well as advantages, not found in analogies from everyday life. The major disadvantage was that the vehicle was not already known by most students, thus it required much careful explanation before it could be compared to the target concept. The advantage over known analogies was that the component parts of the vehicle could be constructed to exactly match the components of the target. Mapping of target on the vehicle was complete.

The analogy was placed as an advanced organizer before the explanation of the process of aerobic respiration in the experimental version of the text. Then when the process was explained, references to the similar aspects of the analogy were made.

The two versions of the text were kept comparable in readability and length. Reading level of both versions was grade 8 on the Flesch-Kincaid scale (Kincaid, 1980). To balance the length of text in the two versions, two pages of related material from earlier in the textbook chapter were added to the control text on respiration. The total length of text in both versions was seven pages. A diagram from the textbook showing the stages in cellular respiration was reproduced in the control text version. A modified version of this diagram plus a second diagram of the analogy vehicle were included in the experimental analogy version.

Dependent Variables

The dependent variables for this study were immediate and delayed recall of the science content in the passages read by the students. Recall, including comprehension and application of knowledge, was measured by multiple-choice tests developed by the researcher. Each test instrument is described below. Characteristics of all achievement tests are summarized in Table 1.

Immediate recall of the science content was assessed for each of the two topics with 20-item four-alternative multiple-choice tests. Items were written by the researcher to test knowledge, comprehension, and application levels of learning as defined in Bloom's taxonomy (Bloom, 1956). The content tested was that which was common to both the textbook and the experimental analogy versions of the text. Test questions were matched to the key concepts of each topic. Content validity was established by submitting texts and test items to a panel of science educators. The panel agreed that the tests were not biased toward either text version and that the questions measured knowledge, comprehension, and application of content found in the two text versions. Rater agreement on the best answer for each item among five science educators was 95% on the evolution topic test and 92% among three science educators on the cellular respiration topic test.

Delayed recall of science content was assessed two weeks after the treatment was completed. The Delayed Recall instrument was composed of selected questions from the two immediate recall tests. One question was selected for each of the 10 concepts within the evolution topic and for each of the eight concepts within respiration. Two additional questions were selected from the respiration test to produce a total of 20 questions, 10 from each topic, for the Delayed Recall test.

Table 1

Characteristics of Content Achievement Tests

Name	Number of Items	Mean Item Difficulty	Reliability (KR 20)	Rater Agreement
Immediate Recall Evolution Topic	20	.47	.63	95%
Immediate Recall Respiration Topic	20	.39	.43	92%
Delayed Recall Both Topics	20	.40	.54	97%

Results

Two treatments were contrasted in this study: the experimental treatment text including extended verbal analogies and the control text with no analogies. Three posttests of biology achievement were given: Evolution Immediate Recall, Respiration Immediate Recall, and Delayed Recall. Unadjusted means and means adjusted for the previous six-weeks biology grade for each group are reported in Table 2. The experimental treatment group scored higher on all tests than did the control group. Adjusting the means did not change this relationship on any of the tests.

Effect sizes were calculated for each achievement measure in terms of standard deviation (SD) units of the control group. An effect size of 0.3 or greater is generally considered educationally significant. The experimental treatment increased achievement on the evolution test 0.27 SD units and 0.18 SD units on the respiration test. The greatest effect was measured on the Delayed Recall test: 0.60 SD units (see Table 2).

Achievement scores on the three posttests were analyzed with three separate analysis of covariance (ANCOVA) procedures with treatment group as an independent variable and previous six-weeks biology grade as a covariate. Results of the ANCOVAs are reported in Tables 3, 4, and 5. (Tables include two additional independent variables, sex and cognitive ability level, which are not discussed in this paper. For details see Radford, 1989.)

The analogy treatment group scored significantly higher ($p = .038$) than the control group on the evolution test and on the Delayed Recall test ($p < .001$). The difference between group means on the respiration test was nonsignificant ($p = .240$).

Table 2

Means, Adjusted Means, Standard Deviations, and Effect Sizes
For Biology Achievement Tests by Treatment

		Achievement Tests											
		Evolution				Respiration				Delayed Recall			
Treatment Group	n	$\bar{X}$	Adj.$\bar{X}$*	SD	ES	$\bar{X}$	Adj.$\bar{X}$*	SD	ES	$\bar{X}$	Adj.$\bar{X}$*	SD	ES
Experimental	89	9.89	10.02	3.20	.27	8.12	8.17	2.88	.18	8.98	9.01	2.80	.60
Control	87	8.76	9.10	3.42		7.57	7.69	2.60		7.03	7.24	2.94	

* Means adjusted for previous 6-weeks Biology grade

Table 3

Analysis of Covariance Summary
For Evolution Content Achievement

Source	df	SS	MS	F	p
Treatment	1	36.46	36.46	4.39	.038
Cognitive Level	2	395.66	197.83	23.82	.001
Sex	1	4.61	4.61	0.56	.457
Error	170	1411.94	8.31		

Table 4

Analysis of Covariance Summary
For Respiration Content Achievement

Source	df	SS	MS	F	p
Treatment	1	9.85	9.85	1.39	.240
Cognitive Level	2	76.01	38.00	5.37	.006
Sex	1	5.27	5.27	0.74	.340
Error	170	1203.66	7.08		

Table 5

Analysis of Covariance Summary
For Delayed Recall Achievement

Source	df	SS	MS	F	p
Treatment	1	136.07	136.07	19.56	.001
Cognitive Level	2	152.34	76.17	10.95	.001
Sex	1	7.62	7.62	1.09	.297
Error	170	1182.61	6.96		

Discussion and Implications

Students in the experimental analogy treatment group clearly show greater delayed recall of biology content than students in the control group. The adjusted mean scores out of 20 questions on the Delayed Recall test were 9.01 for the group that read the analogy text and 7.24 for the control group. This difference was statistically significant at the .001 level. The effect size of 0.60 indicates that the treatment was educationally significant as well.

Several aspects of the results on the Delayed Recall test need consideration. First, the mean score is rather low. The overall mean of 8.01 represents a score of only 40% of the 20 possible correct. Only eight out of 176 students got at least 14 correct, the minimum needed to pass if passing is 70%. The test was very similar in format to those given by the students' biology teachers. If this test were a part of the students' evaluation for a grade, the majority of the students would fail. Why did they do so poorly on this test?

Possible reasons for the low grades on this test include the difficulty of the topics tested, treatment conditions, and student attitude. The topics of evolution and cellular respiration were deliberately selected because they are difficult topics for students. If the topics were too easy, then the advantage of analogies as aids to learning would not be revealed; students in both groups would do well.

Treatment conditions may have contributed to low scores. Both the analogy and control text versions had been pilot tested to insure that students could read the text in the time allotted. But reading the text is not the same as studying the text. The minimal study time available to the students is reflected in student responses on a questionnaire

given to a sample of 21 students from the analogy treatment group after the treatment. In responding to the question "Did the analogies help you remember the science concepts," one student said, "Some. It would have if I really sat down and studied it." A more realistic treatment condition may have been for the students to take their text booklets home to read and study in preparation for a quiz the following day. This technique was considered in planning the research design, but it was felt that the threats to validity due to uncontrolled treatment conditions and differing student history out of the classroom outweighed the disadvantages of short learning time in the classroom.

An additional treatment condition may have led to lower test scores through its effect on student attitude. Although the test was given in the familiar classroom setting, the conditions were not identical to normal classroom testing procedures. The students knew that the test would not affect their grades. Many of them seemed to rush through reading the treatment text and taking the test. This lack of full effort to learn the material and select the best answer on the tests could explain the low test scores and may have also contributed to the rather low reliability of the test (KR 20 = .54).

The encouraging finding based on the Delayed Recall test results is that, in spite of the above problems, the analogy treatment group scored significantly higher than the control group. This significant difference was present when the subscores representing the evolution topic and the respiration topic were analyzed as well as when the overall Delayed Recall test scores were compared. Both analogy treatments were effective in promoting long term (two weeks) retention of learning.

Results on the two immediate recall tests were somewhat less conclusive than those on the Delayed Recall test; the results were significantly in favor of the analogy treatment group on one of the topics, but not on the other. On the Evolution Immediate Recall test the analogy treatment group scored significantly higher ($p = .038$) than the control group. Both groups did better on this test than on either the respiration test or the Delayed Recall test. Possible reasons for the better scores on the evolution test could be that the topic was easier or the test was easier. A possible reason for the superior performance of the analogy group on the evolution test compared to the respiration test could be that the analogy developed for the evolution topic was a more effective analogy than the analogy developed for the respiration topic. This difference in analogies deserves more specific consideration.

One of the requirements for effective instructional analogies revealed by research is that the vehicle should relate to the students' everyday experience (Keane, 1987). The vehicle selected for the evolution analogy was the automobile industry. Responses from a sample of 21 experimental group students given a posttreatment questionnaire provided additional evidence on the effectiveness of analogies and the importance of a familiar analogy vehicle. A large majority of the students (81%) said that analogies helped them understand the science concepts, and nearly as many students (71%) said that analogies helped them remember the science concepts. When asked which particular analogies helped them the most, 84% of the students listed the car analogies in the evolution topic. Only 16% of the students found the wheelbarrow scenario from the respiration topic more helpful. The student responses and the difference in mean test scores for the two

topics re-emphasize the importance of selecting a familiar, easily understood vehicle for the analogy.

Immediate recall of content on the respiration topic was not as complete as for the evolution topic. The means of both treatment groups were lower than the means on the evolution topic, and the difference between means of the two groups was nonsignificant ($p = .240$).

Probable reasons for this decreased achievement relate to the difficulty of the topic and the lower instructional quality of the analogy. As explained above, only 16% of the students surveyed found the wheelbarrow analogy helpful. Typical student comments included, "The wheelbarrow analogy was very complex and I didn't understand it," and "(Analogies) helped a lot on evolution. I just didn't understand the respiration." This is additional evidence that, to be effective, analogies must link familiar, easily understood vehicles to the unfamiliar target. It may be that in the case of cellular respiration the target concepts were so complex that even the analogy treatment did not help, especially in the limited time available for learning the content material.

This study has implications for teachers and textbook authors who want to help students learn complex material. This study has shown that the use of analogies in biology text can increase student achievement. Student comments indicate that they enjoy and believe they benefit from analogies: "I felt that the analogies used in Evolution were very helpful, plus they made the reading and learning more exciting."

But analogies must be good to be useful. Good, like beauty, is in the eye of the student beholder. A few students found the respiration analogies helpful. Most students who responded to the questionnaire

indicated that they were helped more by the automobile analogies in the evolution unit. Their performance on the achievement tests supports the effectiveness of the automobile analogies.

Just as we can usually reach some common judgment about a standard of beauty, we can accept a standard for judging a good instructional analogy. This research study has provided some support for the proposed model of an effective analogy. While all of the steps listed in the model for developing effective analogies are probably important, these three criteria for selecting effective instructional analogies seem to be essential:

1. Select the analogy vehicle from the everyday experience of the intended audience.

2. Integrate the analogy throughout the content text material.

3. Compare the analogy vehicle and target point by point as the various concepts are introduced in the text.

The literature on instructional analogies and the results of this study agree on the importance of two of the above conclusions: selecting a familiar analogy vehicle and comparing the vehicle and target point by point. Integrating the analogy throughout the content text is supported by the literature, but so is the placement of the analogy as an advance organizer. In this study, the success of the evolution topic in which the analogy was integrated throughout the content as compared to the respiration topic in which the analogy was placed as an advance organizer suggests that integration of the analogy is the more effective placement. However, because of other variables that may have influenced the achievement differences on the two topics, a definitive answer on the best placement for the analogy will need to await further

research. In the meantime, teachers and authors wanting to use analogies to aid learning may want to follow the placement that was successful in this study, integrating the analogy throughout the content material.

The effectiveness of analogies as instructional aids has been reported in the literature cited in this study. This study supports previous findings and demonstrates that well-chosen extensive analogies integrated throughout the content text can be effective in promoting achievement. The general recommendations based on these findings for teachers and textbook authors are these: Good analogies work to increase student achievement. Find good analogies and use them.

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